Impurity hardening in AlGaN by Si-doping

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The use of low-temperature deposited buffer layer [1] and the realization of conductivity control by Si-doping [2] and Mg-doping with special treatment [3] have led to fabricate several novel devices such as bright blue and green light emitting diodes and violet laser diodes. AlGaN /GaN hetero-junction is one of the most important structure in such devices, although crack generation caused by the lattice mismatch between AlGaN and GaN is one of the most serious problem in fabricating this structure. We found that crack generation does not only depend on thickness and alloy composition of the AlGaN layer, but also depend on Si concentration in AlGaN. It was also found that Si-doping induces hardening of AlGaN, which is so called impurity hardening effect.

$Al_{0.1}Ga_{0.9}N$:Si/GaN/LT-GaN/Sapphire with various Si concentrations [Si] were grown by metalorganic vapor phase epitaxy. SiH_4 was used as precursor of Si. [Si] in some samples was determined by SIMS, and that of the others was estimated from the SiH_4 flow rate during growth. Alloy composition in AlGaN was ex-situ determined by the high-resolution X-ray diffraction (XRD) using (0002) and $(20\bar{2}4)$ diffraction taking account of the effect of strain [4]. Biaxial stress and the growth rate was in-situ monitored by multi-beam optical stress sensor (MOSS) system [5], by which we can precisely determine the critical thickness ($d_{cri.}$) of the AlGaN at which cracks generate. Before cracking, AlGaN was grown under constant tensile stress.

Figure 1 shows dependence of the biaxial stress during growth of $Al_{0.1}Ga_{0.9}N$:Si on [Si]. Stress increases with increase of the [Si]: Strain of the AlGaN as measured by XRD is almost the same in these samples. These results undoubtedly show that impurity hardening occurred in AlGaN by Si-doping. Figure 2 shows the [Si] dependence of the $d_{cri.}$. The d_{cri} drastically decrease with increase of [Si].

This finding is very important for the design and fabrication of novel devices based on AlGaN/GaN heterostructure. Effect of other impurity doping such as Mg in AlGaN will be discussed.

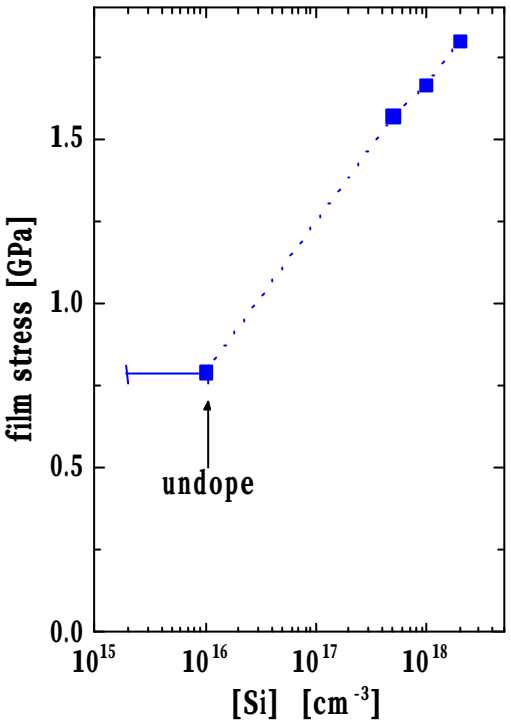

Fig.1 Dependence of film stress on [Si]. The film stress is the biaxial stress during growth of $Al_{0.1}Ga_{0.9}N$:Si.

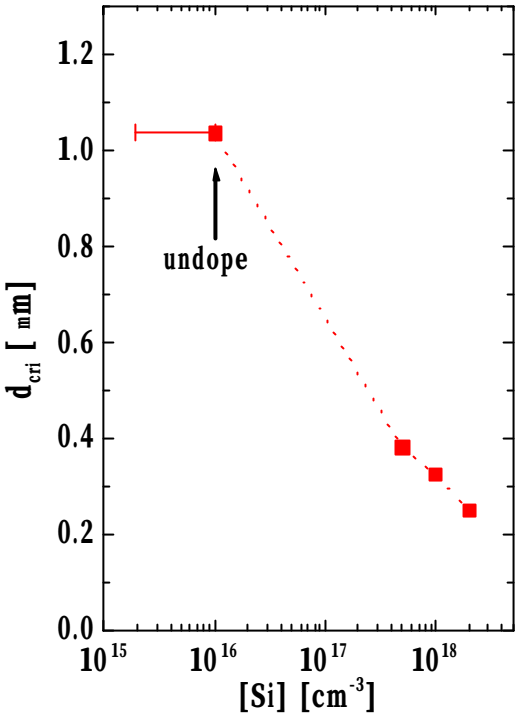

Fig.2 Dependence of d_{cri} on [Si]

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